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MEASURING AIR QUALITY

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

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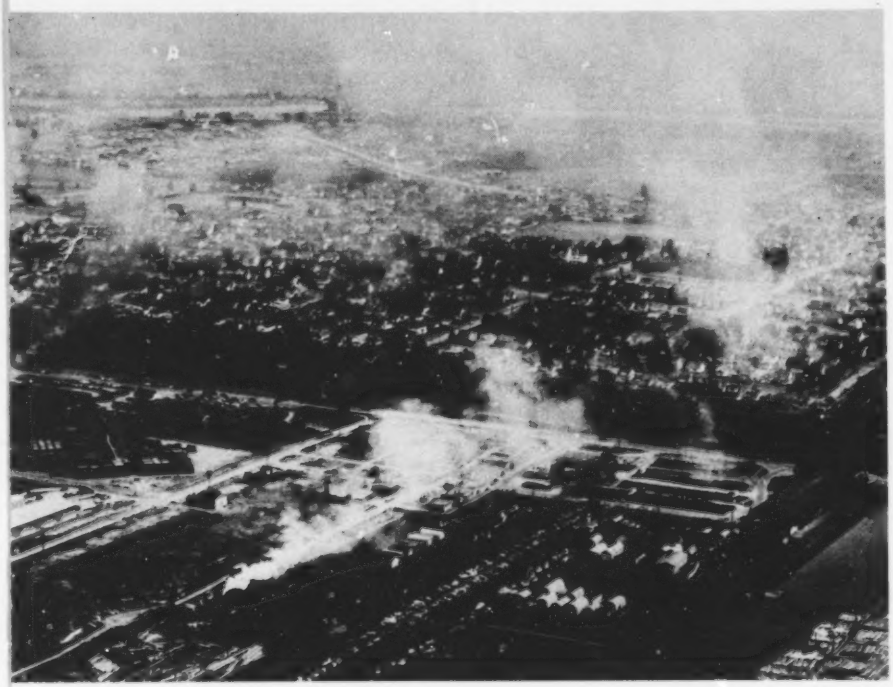
MEASURING

AIR QUALITY

U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Public Health Service

Division of Air Pollution
Laboratory of Engineering
and Physical Sciences

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio



Air pollution ranks high among the significant community problems of 20th century living. The problem of air pollution grows more severe each day, especially in large cities, where the air is loaded with many kinds of polluting substances.

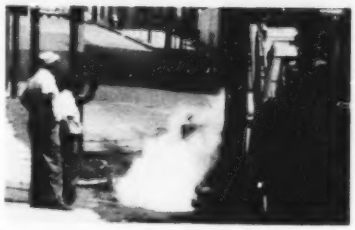
What Is An Air Pollutant?

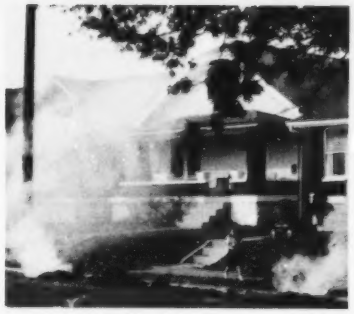
The effects of air pollutants are familiar: they can irritate the eyes, cause objectionable odors, soil curtains, blacken paint, corrode metal and stone, deteriorate rubber, and reduce visibility. Current estimates of the costs of damage caused by air pollution each year run as high as 11 billion dollars.

These estimates do not include the cost of air pollution damage in terms of human health. Episodes in this country and in Europe have demonstrated that air pollution can cause acute illness and sudden death. These episodes have been disastrous and dramatic. Less apparent, but of great concern to health researchers, are the more subtle effects of long-term exposure to the lower concentrations of air pollutants that occur every day in many urban communities. Continual exposure to these low concentrations of pollutants may cause gradual deterioration of health, chronic disease, and premature death.

Where Do They Come From?

Where do these air pollutants come from? Some of them are natural - dust, sand, and pollen, for example. But many others are man - made, produced by commercial and industrial processes, motor vehicles, incinerators, household heating units, and many activities essential to community living. To understand the air pollution problem of any community, whether urban or rural, we must know what pollutants are in the air, and in what quantities, and where they come from.





To obtain this information we must examine the air around us carefully and systematically. Gathering basic data on the nature and extent of air pollution throughout the United States is an important project of the Division of Air Pollution. The Division's programs of air quality measurement are designed for these functions:

- To detect levels of air pollution.
- To relate these to geographical location, topography, population density, industrial activity, climate, meteorological conditions, and other influences.
- To determine trends in air pollution over a period of years.

Why The Records Are Needed

Many scientists need reliable records of air-pollutant levels. Meteorologists are using them to study the effects of air movement, topography, and precipitation on episodes of air pollution. Agriculturalists are relating air pollutant levels to vegetation damage and effects on livestock. Automotive engineers are searching for ways to control the flow of air-polluting emissions from autos, trucks, and buses. Industrialists are testing new processes that will help clear the air around industrial plants. For these, and for many related efforts to control air pollution, accurate measurements of pollutant levels are essential.

Physicians and medical statisticians also work with air pollution records. Recent medical studies have shown, for example, that more than 200 excess deaths were associated with an air pollution episode in New York City in 1956. Studies have been under way for many years on the relative incidence of lung cancer, emphysema, and other ailments among dwellers in urban and non-urban areas. Records of air pollutant levels, when matched with medical records, should tell us much more about how pollutants in the air affect our health.

Photomicrograph of debris removed from an air filter after 24 hours exposure to the air of an urban community. These pollutants covered less than 1/16 square inch. Typical samples include particles of dust, soot, and flyash; pollens, fibers, specks of vegetation, mineral fragments; and bits of paint, tar, and rust.

Two Basic Kinds Of Air Pollution

Air pollutants may be classified in two basic groups: (1) small solid or liquid particles and (2) gases or vapors. The small particles, which remain in suspension in the air for varying periods of time, are called suspended particulate matter, or simply particulates. These pollutants are regularly collected throughout a system of 225 stations in the United States. Collecting and analyzing gaseous pollutants is much more complex technically, but methods of performing this work are constantly being developed. A special program is conducted also for the collection and measurement of pollutants washed out of the air by rainfall.

Collecting And Analyzing Suspended Particulates

THE NATIONAL AIR SAMPLING NETWORK

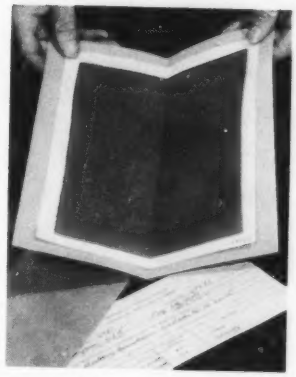
The oldest PHS program of air quality measurement is the National Air Sampling Network (NASN), established in 1953. The NASN is operated in cooperation with health departments, air pollution agencies, and other local organizations. The basic Network consists of 225 sampling stations. Some of these are in operation every year -- 80 in large cities and 35 at nonurban sites that represent farm, forest, desert, or shore exposures. In addition, two groups of 60 stations sample during alternate years. Thus 175 stations are active in the Network in any given year. Each state is served by at least one urban sampling station. NASN sampling stations are operated on a voluntary basis. The cooperation of volunteer workers in maintaining their sampling schedules makes possible a nationwide coverage of both urban and nonurban areas by the NASN.

SAMPLING SCHEDULE

Samples of suspended particulate pollutants are taken from the air once every 2 weeks at each operating station of the NASN. Sampling is performed in accordance with a 'random' schedule prepared by statistical methods. After careful analysis of various possible sampling programs, this type of schedule was adopted as the best means to obtain the maximum amount of information in an economical way. With this schedule the Network can meet its basic objectives. The program yields about 4500 samples per year, as many as the Network's currently available laboratory facilities can handle.

High - volume air sampler

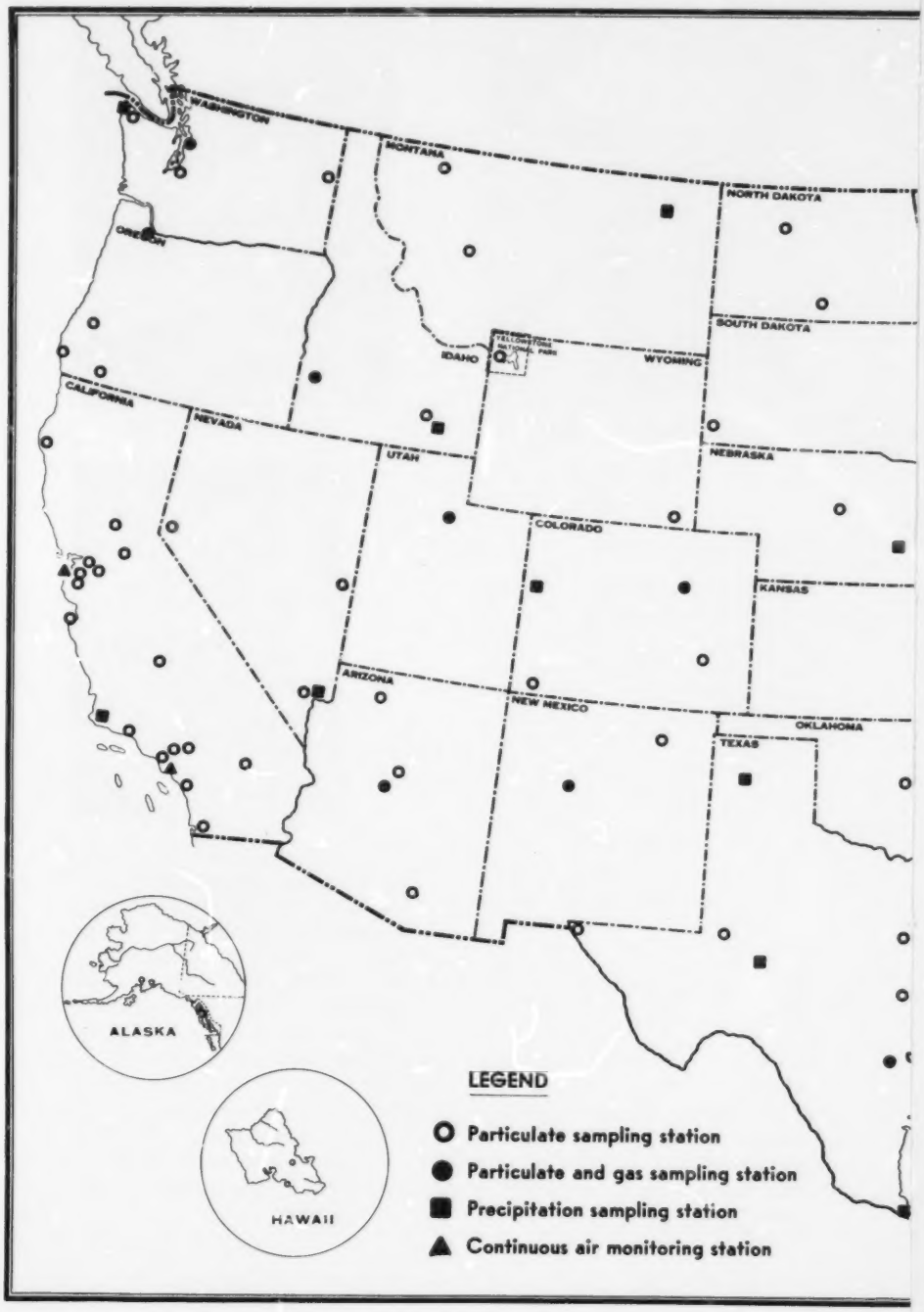
Shelter in a typical site



SAMPLING METHOD

Samples of suspended particulates are collected with a high-volume air sampler, which operates somewhat like a vacuum cleaner. In each 24-hour operating period this sampler pulls about 75,000 cubic feet of air through a filter made of glass fibers. The 8- by 10 - inch filter removes from the air nearly 100 percent of the particles larger than 0.3 micron (a micron is about 1/25,000 of an inch). All filters are weighed at the Sanitary Engineering Center before they are dispatched to the field for use.

Each sampler is mounted in a special shelter, so that the samples may be collected under comparable conditions. In this shelter the flow of air into the filter is directed in such a way that particles too large to remain airborne are excluded and variations caused by shifting winds are minimized. Wherever possible the samplers are situated less than 50 feet above the ground. At the end of each sampling period, the local station operator removes the filter from the sampler, folds it to avoid loss of particulate material in transit, and mails it to the Sanitary Engineering Center for analysis.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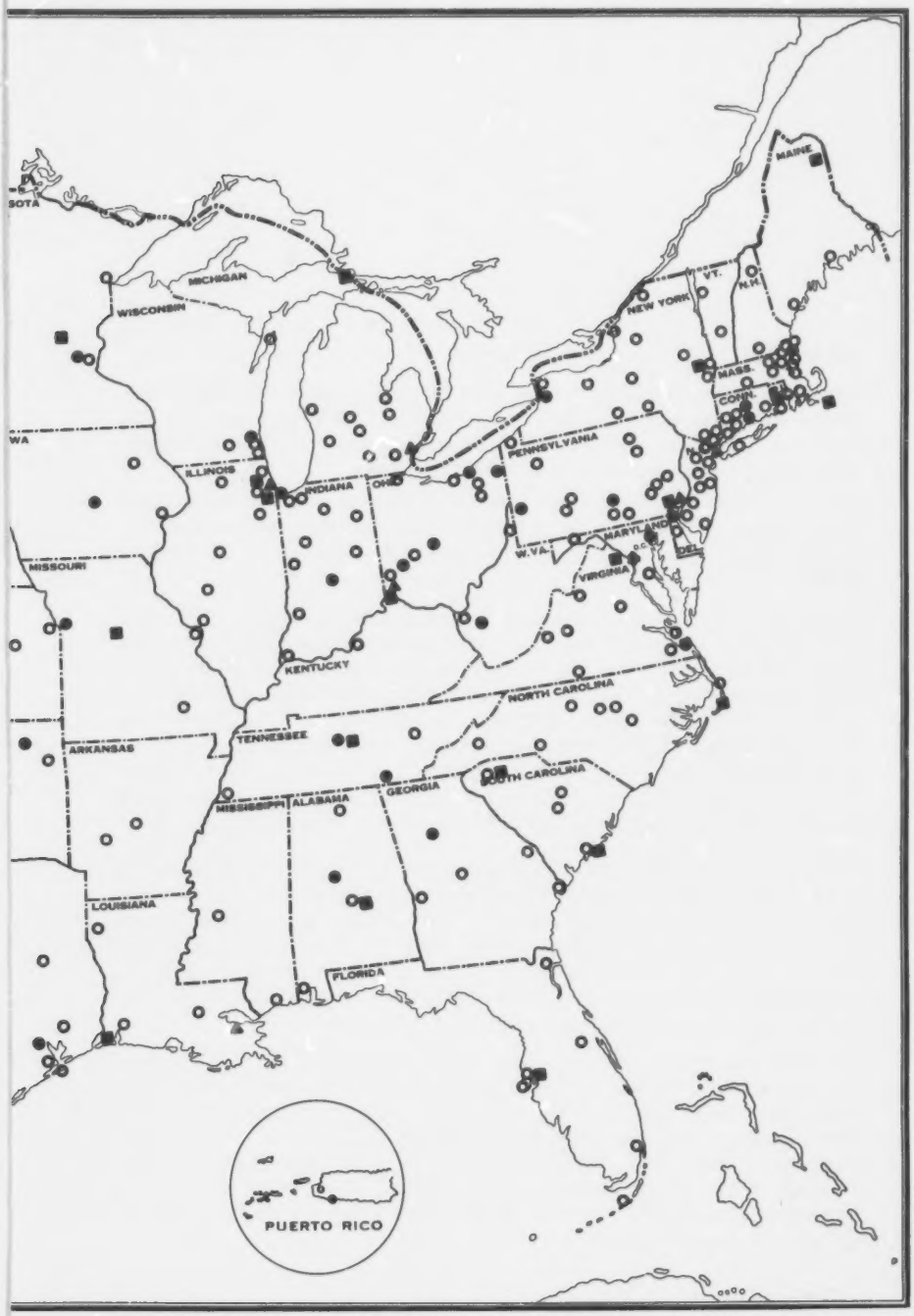
COLORADO
KANSAS
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
ALASKA
HAWAII
LEGEND
Particulate sampling station
Particulate and gas sampling station
Precipitation sampling station
Continuous air monitoring station



MEASURING AIR QUALITY: THE PARTICIPATING STATIONS

ANALYSIS

First the filter is weighed on a sensitive balance to determine the added weight of the collected particulates. The filter is analyzed for gross beta radioactivity and for soiling characteristics and is then divided for chemical analysis.

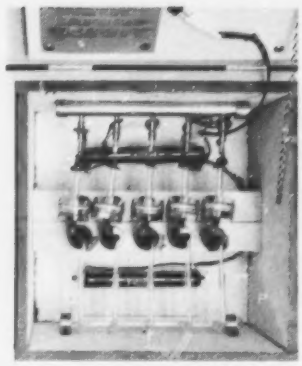
For radioactivity measurements the filters are held for several days before a count is made, to allow the natural radioactivity to decay. The samples still contain measureable quantities of fission products, created by man's use of the atom.

After the radioactivity and soiling measurements are performed, half of the sheet is used for the extraction of organic constituents (oils and tars), which are emitted to the atmosphere from many sources and in a great variety of forms. These substances are removed from the filter sample by a solvent, usually redistilled benzene, and then are subjected to a variety of chemical analyses. Among these 'tarry' organics are substances that cause irritation of animal tissue. Many suspected cancer-producing agents have been isolated from organic matter taken from atmospheric samples.

Part of the second half of the sample sheet is used to determine the inorganic constituents. The inorganic solids found in air samples are chiefly nitrates, sulfates, chlorides, and oxides. Many of these substances can be related directly to specific industrial processes, and their presence in air samples often provides a clue to pollution sources. Nearly all of these inorganic substances contribute to the corrosive action of polluted air.

Another significant group of inorganic air pollutants determined for selected Network samples consists of the metals: antimony, beryllium, bismuth, cadmium, cobalt, copper, chromium, iron, lead, manganese, molybdenum, nickel, silver, tin, titanium, vanadium, and zinc. These pollutants, also, are often directly related to the wastes produced by specific industrial operations and urban activities. Many of these metals are known to be toxic at certain concentrations.

Monitoring The Air For Gases



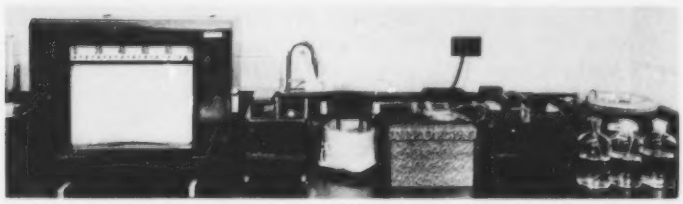
Gas - sampling kit

THE NASN GAS-SAMPLING PROGRAM

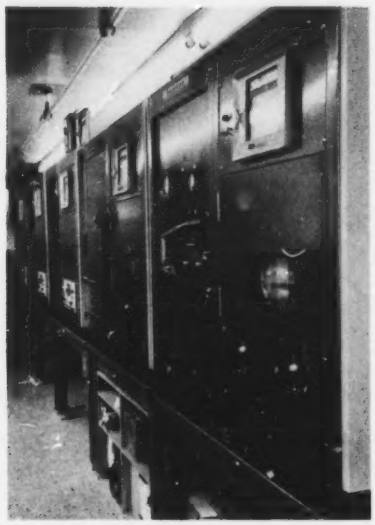
Several common gaseous pollutants are now being sampled at more than 50 stations of the National Air Sampling Network. These samples are collected during the 24-hour sampling period regularly scheduled for particulate sampling at each station. It is hoped that eventually every station that now collects particulates will also be equipped for gas sampling.

The gas-sampling equipment in use at the NASN stations is designed to collect as many as five gases simultaneously. Currently, nitrogen dioxide, sulfur dioxide, and oxidant are measured. When sampling and analytical procedures are developed further, additional gaseous pollutants will be collected and analyzed.

A small pump at the back of each gas sampler creates a vacuum that draws sample air simultaneously through a number of liquid solutions selected to collect specific gaseous pollutants. The pollutant gas in the sample air, which passes through the solution as tiny bubbles, is absorbed by the liquid. When the sampling period is over, the tubes that contain the sample solutions are shipped to the Sanitary Engineering Center for analysis. Automatic analyzers are used to determine the concentrations of gaseous pollutants that were in the sampled air.



Autoanalyzer



THE CONTINUOUS AIR MONITORING PROGRAM

A recently developed program of continuous air monitoring supplements the periodic sampling schedules of the National Air Sampling Network by providing, in nine major urban communities, a battery of automatic instruments that measure continuously the concentrations of seven important gaseous pollutants: sulfur dioxide, nitric oxide, nitrogen dioxide, carbon monoxide, total oxidants, total hydrocarbons, and ozone. The continuous air monitoring stations are also instrumented to collect particulates and precipitation and are equipped with meteorological instruments to record weather conditions that affect the dispersal of air pollutants. In the initial phase of the program, continuous air monitoring stations are being operated in Chicago, Cincinnati, Detroit, Los Angeles, New Orleans, New York, Philadelphia, San Francisco, and Washington.

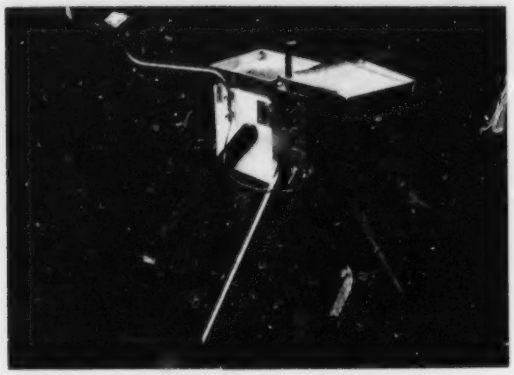
Automatic sampler-analyzers have been developed especially for the Continuous Air Monitoring Program. To monitor the seven different types of gases effectively, several different principles of detection and analysis are used. These include measurement by the absorption of infrared rays, by changes in electrical conductivity, by changes in color of the solution in which the sample is collected, by flame ionization, and by coulimetric methods. A brochure has been published that describes these instruments and detection methods in detail.*

*Continuous Air Monitoring Program, obtainable from the Air Quality Section, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

Continuous air monitoring station

Processing of data in the Continuous Air Monitoring Program is highly automated. Each analyzer is equipped with a companion recording unit, which displays on its chart a continuous record of pollutant levels. In addition, a tape is punched automatically at 5-minute intervals to provide an averaged reading that can be used in machine computation. At the Sanitary Engineering Center the punched-tape data are transferred to magnetic tape and then are analyzed and tabulated on a computer.

The 50-station gas sampling network and the continuous monitoring stations augment the over-all program of air quality measurement in many ways. The gas sampling network incorporates many more stations, but provides fewer analyses; results from this network take the form of 24-hour average values for gaseous pollutant levels. The continuous monitoring stations represent an intensive effort in a few major urban communities to obtain continual readings of a greater number of significant pollutants. Since measurements in these two programs are obtained under different schedules and by a variety of sampling instruments, PHS scientists and other air-pollution researchers may compare and evaluate the two sets of records and integrate them with the records of pollutant levels provided by the larger network of particulate sampling stations.



Automatic precipitation sampler

Precipitation Sampling

A program has been established by the Division of Air Pollution and the U. S. Weather Bureau for the analysis of monthly precipitation samples collected at about 30 stations. The samples are collected in receptacles especially designed to open only during periods of rainfall. Thus these samples contain only the pollutants carried by precipitation and do not collect ordinary dustfall. The samples are shipped to the Sanitary Engineering Center and are analyzed for essentially the same constituents determined for particulate filter samples. In determining the character of pollutants removed from the atmosphere by precipitation, this program introduces still another technique for the study of air pollution throughout the United States.

State-Operated Air Quality Evaluation Programs

At the present time several states are operating air sampling programs. For these programs the equipment, procedures, schedules, sample analysis, and data handling are compatible with those of the NASN, and data are processed without modification. This type of participation by state and local agencies and by university research programs helps meet the increasing need for accurate air quality measurements.

What The Records Show

PARTICULATE POLLUTANTS

Over a period of years the National Air Sampling Network has accumulated extensive data concerning pollution of the atmosphere by particulates. The table below summarizes briefly the concentrations of particulates for urban and nonurban areas on a national basis for a 4-year period.

		CONCENTRATION, micrograms per cubic meter		
		Min.	Max.	Avg.
NATIONAL URBAN (128 Stations)	Suspended Particulate Matter	10	1706	124
	Benzene - Soluble Organics	0.1	123.9	10.2
NATIONAL NON URBAN (45 Stations)	Suspended Particulate Matter	1	461	37
	Benzene - Soluble Organics	0.1	13.7	1.7

Comparing the average urban and nonurban contaminant levels gives unquestionable evidence of air pollution in American cities. The average concentrations of organic contaminants, for example, are about 6 times higher in cities than in nonurban areas.

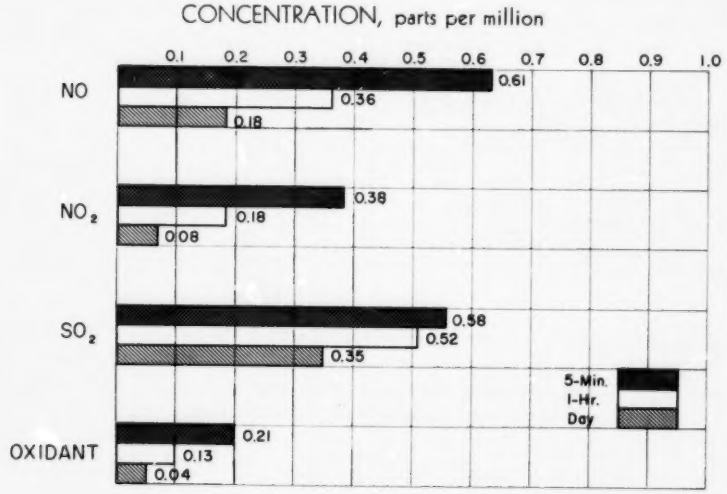
GASEOUS POLLUTANTS

The NASN gas-sampling program provides a measure of gaseous pollution very much like that of the particulate sampling operations. Here is a summary of the gas-sampling data taken during one year for two important pollutants:

	CONCENTRATION, parts per million		
	Min.	Max.	Avg.
SULFUR DIOXIDE	0.01	0.40	0.03
NITROGEN DIOXIDE	0.01	0.26	0.05

These figures represent over 770 samples taken during the year at 47 stations. They show the average concentrations of pollutants over a 24-hour sampling period, providing a useful 'background' picture of gaseous air pollution in many areas of the country.

Periodic sampling, however, gives no information about the higher concentrations that occur for short periods during the relatively long sampling interval. Such information is needed in our efforts to trace air pollution to its sources and to engineer devices for pollution control. The Continuous Air Monitoring Program provides this important data. The chart below, which summarizes the continuous air monitoring data for one month, shows that the average pollutant levels recorded at 5-minute intervals may be as much as 5 times higher than the average over 24 hours.



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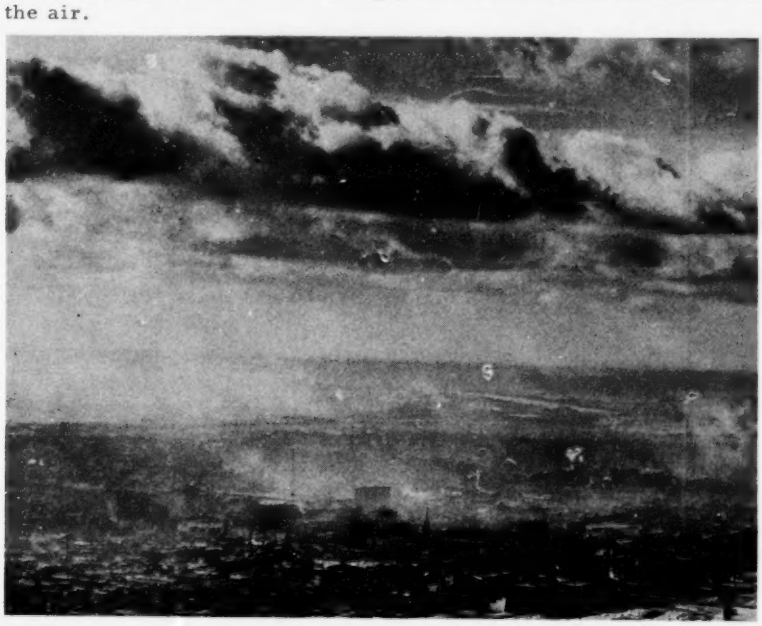
Because the Public Health Service programs of air quality measurement are limited in manpower and equipment, it is imperative that the operations provide the maximum amount of useful data. Although the measurements now in progress, and those needed in the future, are varied and complex, the methods of sampling and analysis are intended to be as simple and flexible as possible. Flexibility is important in the monitoring of air quality, because pollution of the air is by no means a static condition.

Pollution patterns are different in each community, and in each community they undergo continual change. As giant urban complexes are developed, as rural living is transformed, and as new products and processes are evolved, the nature of atmospheric pollution will reflect these changes.

We now recognize that human health and comfort are severely threatened by contaminated air and that the threat assumes new forms from day to day. For this reason new techniques for sampling and analysis are continually under study so that PHS scientists may provide an increasingly accurate account of what is in the air.



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*Available without charge. Address requests to Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, O.

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PHS-637-Air Pollution Meaurements of the National Air Sampling Network, 1953-1957. 259 pp. $2.00. (Out of print)

PHS-978-Air Pollution Measurements of the National Air Sampling Network, 1957 - 1961.

[+]No longer in stock at the Center. Must be obtained from publisher or a library collection.

[++]Available by purchase. Address requests to Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.